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Experiment No: 04

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Experiment Name: Experiment on

1. Detection of Time Delay Using Cross-Correlation

2. Determination of Z-Transform

3. Determination of Zeros & Poles

Theory :

Cross Correlation:. This is a kind of correlation, in which the signal in-hand is correlated with another signal so as to know how much resemblance exists between them. Mathematical expression for the cross-correlation of continuous time signals *x* (*t*) and *y* (*t*) is given by

$$R_{xy}(\tau)=\int_{-\infty}^{\infty}x(t)y^{\star}(t-\tau)dt$$

Similarly, the cross-correlation of the discrete time signals *x* [*n*] and *y* [*n*] is expressed as

$$R_{xy}[m]=\sum_{n=-\infty}^{\infty}x[n]y^{\star}[n-m]$$

Next, just as is the case with autocorrelation, cross-correlation of any two given signals can be found via graphical techniques. Here, one signal is slid upon the other while computing the samples at every interval. That is, in the case of digital signals, one signal is shifted by one sample to the right each time, at which point the sum of the product of the overlapping samples is computed.

Z-Transform: The Z-transform is a mathematical transform used in the field of signal processing and system analysis. It is a discrete-time counterpart of the Laplace transform, which is used for continuous-time signals and systems.

The formula for the Z-transform is defined as follows:

X(z) = ∑[x(n) * z^(-n)]

Where:

- X(z) represents the Z-transform of the discrete-time signal x(n).
- x(n) is the discrete-time signal.
- z is a complex variable.

In this formula, x(n) is multiplied by z^(-n), where n is the index of the discrete-time signal. The sum is taken over all possible values of n, which can be negative, zero, or positive.

Zeros & Poles: In the context of the Z-transform, zeros and poles refer to the locations in the complex z-plane where the numerator and denominator of the transfer function of a discrete-time system become zero, respectively. Zeros and poles play a crucial role in understanding the behavior and characteristics of the system.

Let's consider an example to illustrate zeros and poles:

Suppose we have the following transfer function of a discrete-time system:

$H(z) = (z - 1) / (z - 0.5)$

In this transfer function, we have a zero at $z = 1$ and a pole at $z = 0.5$.

Zeros: Zeros of a transfer function are the values of z for which the numerator of the transfer function becomes zero. In our example, the zero is located at $z = 1$. When z takes the value of 1, the numerator of H(z) becomes zero, indicating that the system output becomes zero at that particular value of z.

Poles: Poles of a transfer function are the values of z for which the denominator of the transfer function becomes zero. In our example, the pole is located at $z = 0.5$. When z takes the value of 0.5, the denominator of H(z) becomes zero, indicating that the system response becomes infinite or unstable at that particular value of z.

Software: MATLAB

Code:

Time Delay of Two Signals Using Cross-Correlation:

```
clc;
clear all;
close all;

t = 0:0.01:20;
a_1 = t>=10 & t<=15;
a_2 = t>=12 & t<=15;
signal_1 = a_1 + a_2;
a_3 = t>=5 & t<=10;
a_4 = t>=7 & t<=10;
signal_2 = a_3 + a_4;

[z,delay] = xcorr(signal_1, signal_2);
cross_correlation = z/max(abs(z(:)));

subplot(3, 1, 1);
```

```
    plot(t, signal_1);
    title('Given Signal');

    subplot(3, 1, 2);
    plot(t, signal_2);
    title('Delayed Signal');

    subplot(3, 1, 3);
    plot(delay*0.01, cross_correlation);
    title('Cross Correlation output');

    maximum = max(cross_correlation);
    indexesOfMax = find(cross_correlation == maximum);
    find_delay = delay(indexesOfMax);
    temp = find_delay*0.01;
    display = ['Time Delay is: ', num2str(temp), ' seconds'];
    disp(display);
```

Z-Transform:

```
clc;
clear all;
close all;

syms n z;
x = (1/5)^n + (1/9)^n;
X = ztrans(x, n, z);
disp(X);
```

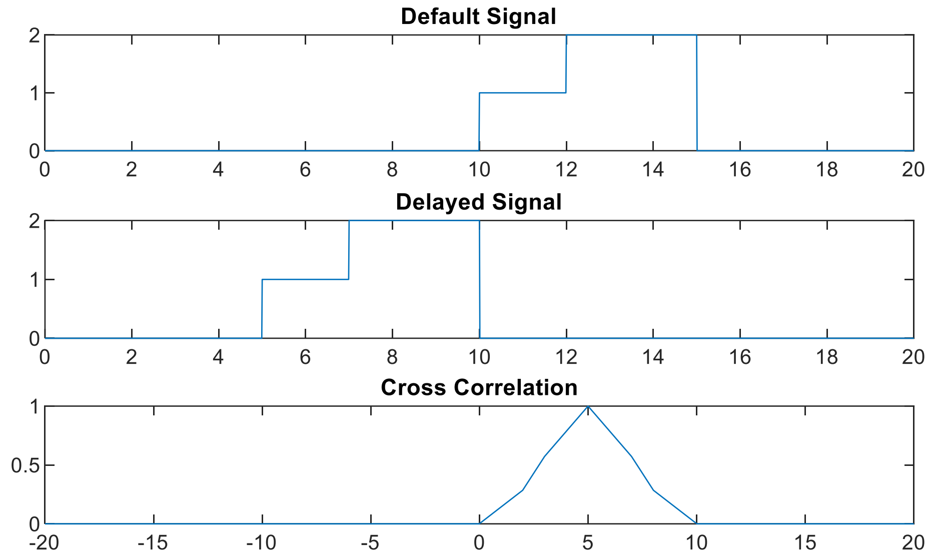
Zeros & Poles:

```
clc;
clear all;
close all;

zeros = -0.2;
poles = 0.5*exp(j*2*pi*[-0.2 0.2]');
zplane(zeros,poles);
```

Output:

Time Delay of Two Signals Using Cross-Correlation:



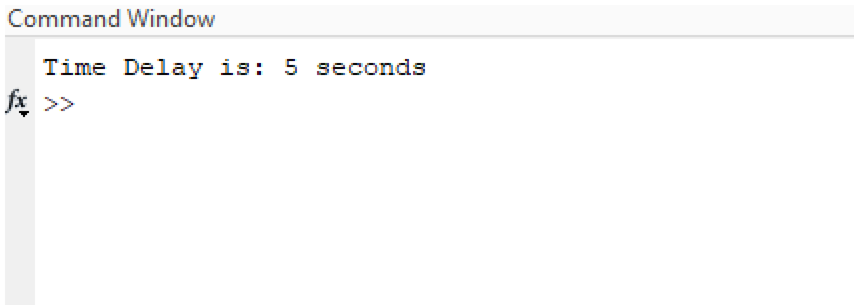


Fig 4.1 Time Delay of Two Signals Using Cross-Correlation

Z-Transform:

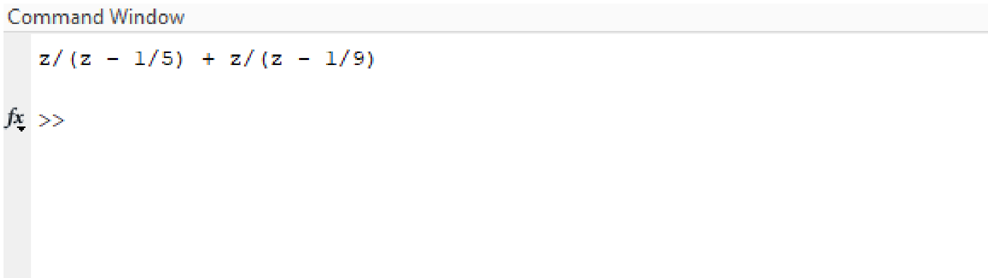


Fig 4.2 Determination of Z-Transform

Zeros & Poles:

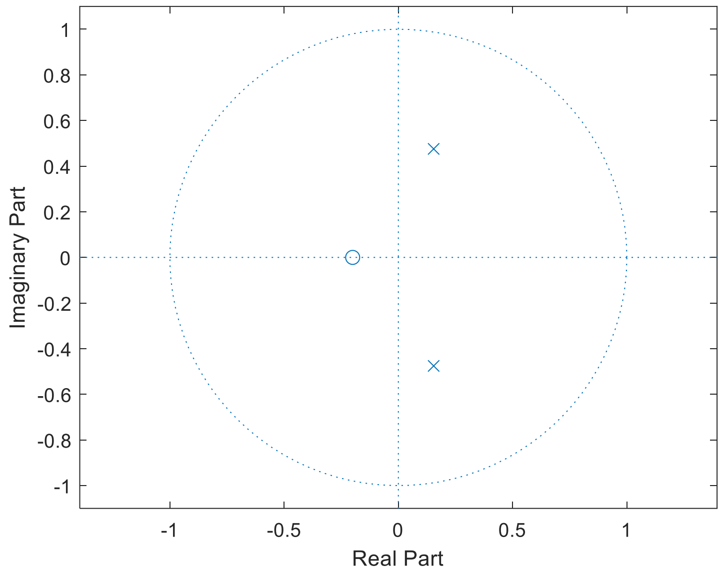


Fig 4.3 Determination of Zeros & Poles

Discussion : By this experiment, we have learned to determine the time delay by using "xcorr" function between a signal and it's delayed version (using cross correlation) in MATLAB. . We find out delay for both the discrete and continuous signal. Then, we experimented with the poles and zeros of the z transform of a signal .

Conclusion : The output graphs and results were as expected which matches theory. The codes worked properly and were executed without any errors. So, we can come to a conclusion that the experiments were done perfectly.